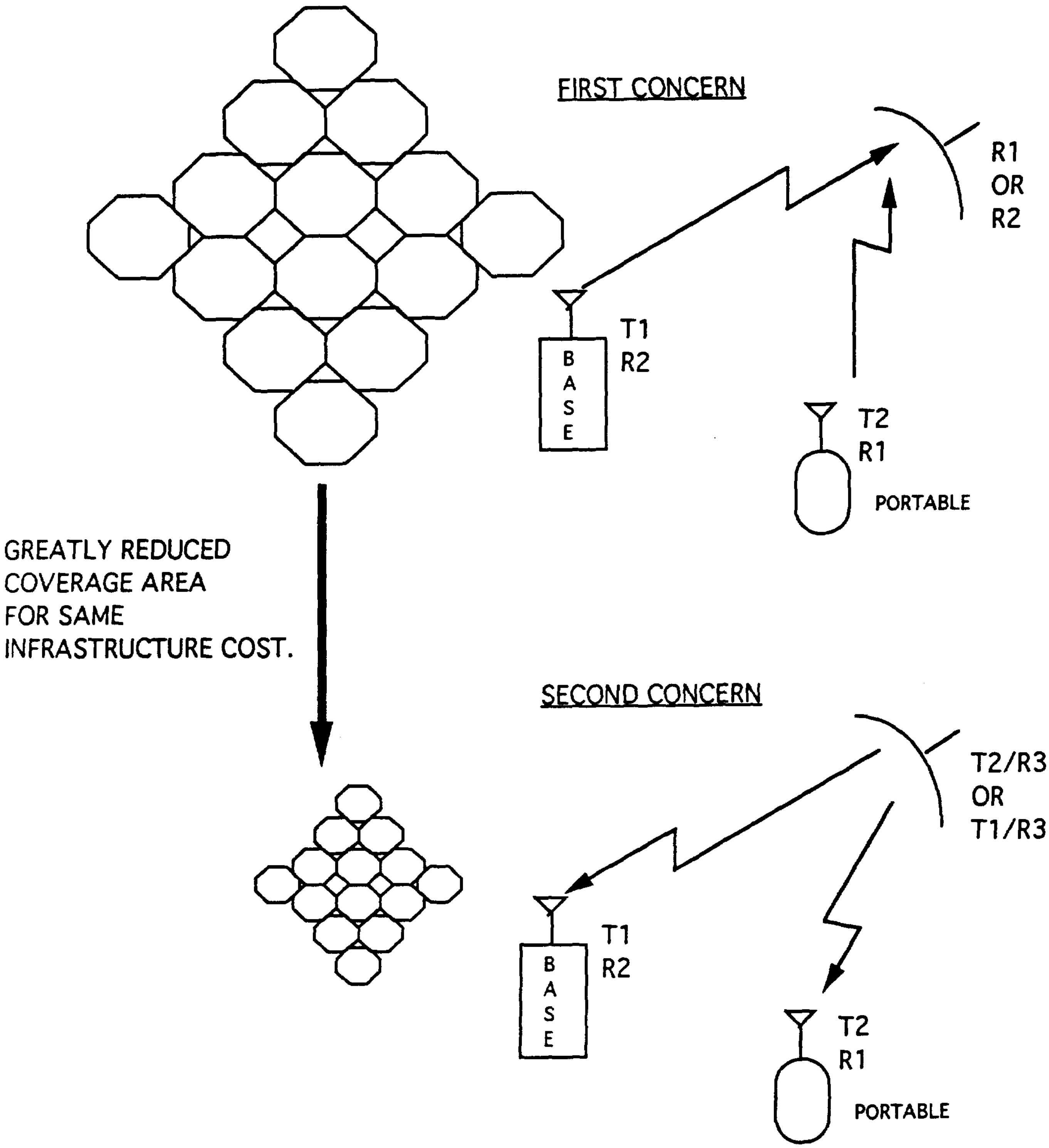
# LEST WE FORGET




CONCLUSION:

REDUCED ECONOMICAL SPECTRUM ACCESS TO LICENSEE.......ESPECIALLY PREVALENT EARLY IN THE SHARING/RELOCATION PROCESS.......OPPOSITE FROM THAT DESIRED (LARGER CELLS, REDUCED OVERALL CAPACITY).

(This figure was generated by Comsearch 7/92.)

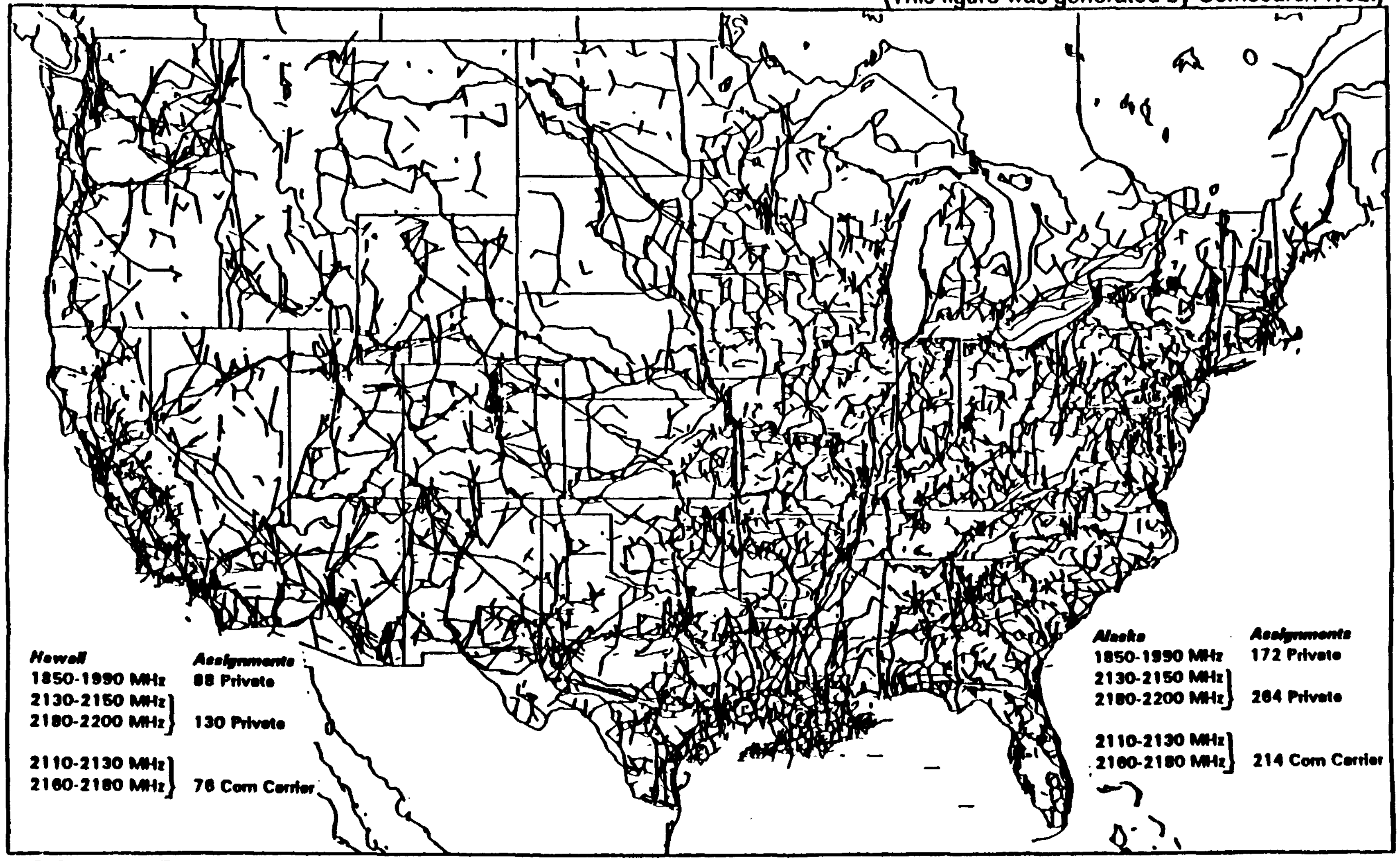



**Figure 5** - Non-government fixed microwave use in the 1850-1990, 2110-2150, and 2160-2200 MHz bands.

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COMMITTEE JEM CONTRIBUTION

| | |
|---|---|
| STANDARDS PROJECT: | Joint Experts Meeting on PCS Air Interface (JEM) |
| TITLE: | The Motorola PPS™-1800 Low-Tier Wireless Personal Communication System |
| SOURCE: | MOTOROLA, INC. |

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| DATE: | NOVEMBER, 1992 |
| DISTRIBUTION TO: | Participants in JEM. |
| NOTICE: | This contribution has been prepared by Motorola Inc., to assist Standard Committees as a basis for discussion and should not be construed as binding on Motorola. Specifically, Motorola reserves the right to request amendments or modifications in the future. |

**Abstract** - This submission describes the proposed PPS™-1800 Low-Tier Personal Communication System that has been optimized for low-cost wireless access to the PSTN over a wide service area. PPS™-1800 Low-Tier Personal Communication System refers to Portable and Fixed Wireless Access subscriber units, Ports (or Base Units) and network interface equipment that, together with a wireline network, will provide a subscriber with high quality voice telephony as well as access to a selection of data services. If the wireline network supports the Advanced Intelligent Network (AIN) then the many features and services provided by AIN will be available. The Motorola PPS™-1800 Low-Tier Personal Communication System embodies many of the concepts described in the Bell

Communications Research (Bellcore) advisories for Wireless Access Communications Systems (WACS) TA-1313 and FA-1318 dated July 1992 and June 1992, respectively.

A high degree of compatibility with the air interface of the Motorola PPS™-1800 High-Tier Personal Communication System is desirable so that economical subscriber units can be developed which can operate in either system, thus granting the subscriber the mobility level appropriate to his particular circumstance.

## Introduction

PPS™-1800 Low-Tier Personal Communication System is part of an overall wireless communication fabric; in this context

- it will provide low-cost, high-quality voice communication and limited data communication to stationary or pedestrian subscribers;
- it will provide ubiquitous service wherever population densities make the provision of such service economically viable;
- it is compatible with and complementary to the PPS™-1800 High-Tier Personal Communication System that will provide:
  a.) mobile service for those subscribers that demand high-speed mobility while communicating, and
  b.) higher power fixed access service for subscribers in rural, or other low population density areas.

Furthermore, the use of validation, authentication and encryption techniques in this system will provide to the subscriber a high degree of secrecy and location privacy and will offer to the system provider reliable billing and a barrier to fraudulent access of services.

## Technical Details

Key system parameters for PPS™-1800 Low-Tier Personal Communication System are presented in Table 1. A comparison of the ISO reference model Layer 1, Layer 2, and Layer 3 aspects of this system with respect to the Motorola PPS™-1800 High-Tier Personal Communication System is included in a companion submission to this meeting.

The frequency allocation is based on the FCC Notice of Proposed Rule Making Gen Docket 92-333 released August 14, 1992. The frequency band will be divided into a number of duplex channels which will be deployed in a frequency reusing arrangement. Port frequencies will be assigned using the Quasi-Static Autonomous Frequency Assignment algorithm proposed by Bellcore as required to ensure 99 percent coverage reliability. The system bandwidth assigned to a service provider will determine the number of frequencies that can be deployed. Too few channels will limit the reuse distance that can be achieved and this in turn may increase interference and reduce the coverage reliability.

A channel spacing of 400 kHz is used in an experimental implementation of the Motorola PPS™-1800 Low-Tier Personal Communication System; however, we anticipate that advances in component and radio design may allow a 350 kHz channel spacing with no degradation in link quality. The impact of total system bandwidth and channel spacing on cell capacity is discussed in a subsequent section of this submission. It should be noted, furthermore, that the PPS™-1800 Low-Tier Personal Communication System concept is extremely flexible; the bandwidth and the bandwidth-determining parameters (number of time slots per frame, channel data rate, etc.) may be scaled to fit in the final spectrum allocations for the 1850 to 1990 MHz band. For maximum flexibility the PPS™-1800 Low-Tier Personal Communication System bandwidth-determining parameters should be compatible with corresponding parameters of the PPS™-1800 High-Tier Personal Communication System.

| Parameter | Specification |
|---|---|
| Frequency Band (NPRM) | 1850.0 - 1895.0 MHz (Downlink)<br>1930.0 - 1975.0 MHz (Uplink) |
| Access Method | TDM / TDMA |
| Duplex Method | Frequency Division (FDD) |
| Channel Planning | Quasi-Static Autonomous Frequency Assignment |
| Diversity (Port) | Post-detection Selection |
| Diversity (Portable) | Antenna Selection |
| Speech Coding | 32 kb/s ADPCM |
| Modulation | 4 - QAM (alpha = 0.5 RC spectrum) |
| Channel Bit Rate | 500 kb/s |
| Channel Spacing | 400 kHz |
| Slot Duration | 100 bits (200 μs) |
| Frame Duration | 10 slots (2 ms) |
| Superframe Duration | 16 ms |
| Error Control Coding | (85,73) FED |
| Average RF Power Out (Port) | 400 mW Min.<br>800 mW Max. |
| Peak RF Power Out (Portable) | 100 mW Min.<br>200 mW Max. |
| Average RF Power Out (Portable)<br>(per full-rate timeslot) | 10 mW Min.<br>20 mW Max. |
| Noise Figure (Port) | 6 dB |
| Noise Figure (Portable) | 8 dB |

Table 1. System Parameters

The choice of TDM/TDMA as the access method and a slot structure consistent with that defined by Bellcore lead to a low-cost and low-current drain implementation of the subscriber unit. The short frame duration results in a low-delay speech path that eliminates the need for echo cancellation in the subscriber unit; this results in a significant cost and power savings. The specified slot and frame structures also support a simple migration to lower rate speech coders as such technology becomes feasible for this application. When possible, such a migration will allow increased system capacity without an increase in infrastructure complexity. In addition, the user can access multiple slots and carry higher rate data when required. TDM on the downlink allows subscriber units to constantly monitor all frequencies allocated to the system and quickly and reliably determine the best channel on which to communicate.

Diversity is employed at both the Port and the Portables or Fixed Wireless Access Units. Post-detection selection diversity is used in the Ports; selection may be made on the basis of received signal strength (RSSI), signal quality, word error rate (WER) or some combination of these measures. The TDM downlink facilitates the use of antenna selection diversity in the subscriber units. Each antenna can be selected in one or more timeslots immediately prior to the user's desired timeslot. The received signal can be measured on both antennas and the antenna with the better signal is selected for use in the user's receive timeslot. At pedestrian speeds and with the short timeslot duration specified for this system the proposed antenna selection diversity scheme performs nearly as well as more complicated methods. [Bellcore's proposal to provide uplink transmit diversity is being studied.]

The full-rate speech coder uses the CCITT standard 32 kbps ADPCM algorithm. This choice provides high quality and low speech path delay; furthermore, efficient integrated circuit implementations are readily available. A superframe overlay described in the Bellcore advisories allows for migration to half-rate (16 kbps) and quarter-rate (8 kbps) low-delay speech coders when they become available. Half-rate and quarter-rate speech coders will coexist with full-rate speech coders in the system as it develops. Early adopters of this service will not be forced to upgrade their portables as the system matures. Furthermore, the radio Ports, which will represent a sizable infrastructure investment, are expected to be transparent to the bearer channel and need not change as this migration occurs. As subscriber units with lower rate speech coders begin to proliferate an effective increase of system capacity will be realized with little additional investment in infrastructure.

Modulation, channel bit rate and framing are consistent with the Bellcore advisories. Raised-cosine filtered 4-QAM at 250 ksymbols/second is used as the preferred modulation technique. This supports a channel bit rate of 500 kbps; since there are 10 timeslots per frame, this results in 50 kbps per full-rate user. Table 2 illustrates the bit assignments in each timeslot. Lower rate speech coders will utilize a timeslot every other frame (half-rate) or every fourth frame (quarter-rate); they will have correspondingly lower per-user rates as shown in Table 3 for the half-rate case. One limiting factor that discourages even lower rate logical channels is the throughput of the associated signaling channel; for a quarter-rate channel this value is already down to 1 kbps.

Error detection, rather than forward error correction, is utilized in the Motorola PPS™-1800 Low-Tier Personal Communication System. At pedestrian speeds the channel appears to be quasi-static; it is either very good, in which case error correction coding is superfluous, or very bad, in which case error correction coding is ineffective.

DOWNLINK

| Data Type | Bits per timeslot | Rate (bits/second) |
|---|---|---|
| Synchronization | 14 | 7,000 |
| Associated Signaling | 8 | 4,000 |
| Word Error Indication | 1 | 500 |
| Speech (or bearer data) | 64 | 32,000 |
| Error Detection Coding | 12 | 6,000 |
| Power Control | 1 | 500 |
| **TOTAL** | **100** | **50,000** |

UPLINK

| Data Type | Bits per timeslot | Rate (bits/second) |
|---|---|---|
| Differential Encoding | 2 | 1,000 |
| Associated Signaling | 9 | 4,500 |
| Speech (or bearer data) | 64 | 32,000 |
| Error Detection Coding | 12 | 6,000 |
| (Spare Bit) | 1 | 500 |
| Guard time | (12) | Not included in total allocation. |
| **TOTAL** | **88** | **44,000** |

Table 2. Full-Rate Channel Bit Allocations

DOWNLINK

| Data Type | Bits per timeslot | Rate (bits/second) |
|---|---|---|
| Synchronization | 14 | 3,500 |
| Associated Signaling | 8 | 2,000 |
| Word Error Indication | 1 | 250 |
| Speech (or bearer data) | 64 | 16,000 |
| Error Detection Coding | 12 | 3,000 |
| Power Control | 1 | 250 |
| **TOTAL** | **100** | **25,000** |

UPLINK

| Data Type | Bits per timeslot | Rate (bits/second) |
|---|---|---|
| Differential Encoding | 2 | 500 |
| Associated Signaling | 9 | 2,250 |
| Speech (or bearer data) | 64 | 16,000 |
| Error Detection Coding | 12 | 3,000 |
| (Spare Bit) | 1 | 250 |
| Guard time | (12) | Not included in total allocation. |
| **TOTAL** | **88** | **22,000** |

Table 3. Half-Rate Channel Bit Allocations

## Services

Services that could be provided by the Motorola PPS™-1800 Low-Tier Personal Communication System are consistent with those presented in the CCIR SG8 document 8/51, "Draft Recommendation: Services Provided on Future Public Land Mobile Telecommunication Systems (FPLMTS.SRVC)." This recommendation provides a framework on which to base detailed service descriptions as they are developed. The range of services that FPLMTS is envisioned to support is extensive and the availability of individual services may be limited by radio equipment design and provisioning of the landline network.

Fixed Wireless Access application of PPS™-1800 Low-Tier Personal Communication System uses the digital radio link as a substitute for the copper drop wire and a portion of the distribution plant. In this application the radio link should be transparent to the subscriber. Service requirements that will be maintained include single party message telephone service, privacy equivalent to wireline, and voiceband data service to the rate allowed by the choice of speech coder. For 32 kbps ADPCM, up to 2400 bps data using standard voiceband modems will not be subjected to significant degradation (per CCITT Recommendation G.721). With this same speech coder, voiceband data modems at rates to 4800 bps may be subjected to additional degradation over and above that expected from standard 64 kbps PCM links.

Portable access application of PPS™-1800 Low-Tier Personal Communication System uses the digital radio link to allow a portable handset to access the telephone network. In addition to the services and features available from the network, certain additional services must be provided to facilitate access by Portables. These services include:

- Terminal Registration and Mobility - this is the process by which a portable terminal registers its location in a registration area.

- Terminal Authentication and Privacy - this is an encryption method that is used to ascertain the identity of the terminal before access is permitted and to ensure the privacy of the subscriber when using the system.

- Call Delivery and Alerting - these services are required to deliver a call to a Portable user. They include the routing of call related messages, alerting the portable subscriber when appropriate and the actual connection of calls.

- Time Slot Transfer and Automatic Link Transfer - these processes switch a call in progress from one time slot to another on a given RF carrier (time slot transfer) or from one RF carrier to another (automatic link transfer) to maintain call quality as the link quality changes due to the dynamic nature of the interference environment or the movement of a portable subscriber.

- Priority Access for Emergency Calls - this procedure provides the capability to a subscriber unit to alert the network of a need to place an emergency call even when all traffic channels are occupied on a Port thus blocking normal access.

• System Information - certain information about the system which can vary between coverage areas or between service providers must be provided to the subscriber unit.

• Power Control of the Portable - this service, if implemented, will provide control of the transmit power of subscriber units. This capability could be used to reduce interference and to prevent overloading the receivers of Ports that are in close proximity of Portables.

The following list of telecommunication services has been extracted from CCIR document 8/51; it represents the types of network services that could reasonably be supported by the Motorola PPS™-1800 Low-Tier Personal Communication System. Some of these services require further definition and special interfaces could be required to support any non-voice service.

Telecommunication Network Services:

a.) voice telephony
b.) message handling service
c.) teletex
d.) paging
e.) facsimile
f.) data (up to 9600 bps)
g.) video services (limited)
h.) short message service

Finally, Motorola PPS™-1800 Low-Tier Personal Communication System embraces the concept of Universal Personal Telecommunications (UPT); the personal mobility aspects of UPT are being considered in the evolution of our system definition.

## Capacity

Total system bandwidth allocated to an operator and the system channel spacing has a direct impact on the system capacity; more RF channels can be assigned within the allocated total system bandwidth as the channel spacing is reduced.

Table 4 presents the traffic per cell (in Erlangs) based on the following range of possible system parameters:

| | |
|---|---|
| TOTAL SYSTEM BANDWIDTH (for a given operator) | 10, 20, 30, 40, 50, and 60 MHz |
| CHANNEL SPACING | 400 kHz, 350 kHz |
| FREQUENCY REUSE PATTERN SIZE | 16, 21, 25 |

There are a number of assumptions behind these results.

1.) The entire system bandwidth allocated to a given operator is used entirely for PPS™-1800 Low-Tier PCS service. If a system operator positions his allocation between this service and PPS™-1800 High-Tier PCS then the bandwidth indicated in the table represents only that segment assigned to low-tier service.

2.) Consistent with recent Bellcore advisories, only 9 of the 10 time slots on an RF carrier can be independently assigned for bearer service. The remaining time slot is reserved for use as a System Broadcast Channel (SBC) which is used for broadcast of pertinent system information and subscriber alerting messages. When a second RF channel is used in a given cell to increase capacity the additional SBC is not required and can be used as a traffic channel. In a very dense system that supports additional RF channels per cell site, the following (conservative) estimate of TDMA channel allocations has been used for capacity estimation.

| RF CHANNELS | SBC TIME SLOTS | TRAFFIC TIME SLOTS |
|---|---|---|
| 1 | 1 | 9 |
| 2 | 1 | 19 |
| 3 | 2 | 28 |
| 4 | 2 | 38 |
| 5 | 3 | 47 |
| 6 | 3 | 57 |

3.) Subscriber blocking of 1% or less is assumed and the Erlang B model is used to calculate the traffic per cell.

4.) Note that, in most cases, the number of RF channels available within the allocated BW cannot be uniformly distributed over the system coverage area given the selected reuse pattern size. For now we consider that the additional RF channels will be assigned to some of the cell sites which will have one more RF channel than the rest. A weighted average of the cell site traffic capacities will then be used.

[Example: For a 30 MHz total BW and 350 kHz channel spacing, 42 RF channels can be assigned. If a 25-cell reuse pattern size is used, then within the repeat pattern 17 of the sites will have 2 RF channels (or 19 traffic time slots) and 8 of the sites will have only 1 RF channel (or 9 traffic time slots).]

For a total system bandwidth of 10 MHz (i.e., 5 MHz duplex pair) there is insufficient spectrum to provide ubiquitous reliable coverage. With only twelve 400 kHz channels or fourteen 350 kHz channels even a 16 cell reuse pattern cannot be obtained. With an allocation of this size a telepoint-like service with "islands of coverage" would result if sufficient reuse distances are maintained to ensure tolerable levels of cochannel interference.

CHANNEL SPACING = 400 kHz

| | TOTAL SYSTEM BANDWIDTH (MHz) | | | | |
|---|---|---|---|---|---|
| REUSE PATTERN SIZE | 20 | 30 | 40 | 50 | 60 |
| 16 | 7.97 | 13.55 | 19.72 | 26.17 | 32.72 |
| 21 | 5.2 | 9.46 | 14.05 | 18.29 | 23.56 |
| 25 | 3.78 | 7.36 | 11.23 | 14.79 | 18.64 |

CHANNEL SPACING = 350 kHz

| | TOTAL SYSTEM BANDWIDTH (MHz) | | | | |
|---|---|---|---|---|---|
| REUSE PATTERN SIZE | 20 | 30 | 40 | 50 | 60 |
| 16 | 9.31 | 15.36 | 23.48 | 30.73 | 38.03 |
| 21 | 6.26 | 11.23 | 16.52 | 21.92 | 27.63 |
| 25 | 4.67 | 8.85 | 13.30 | 17.45 | 22.08 |

TABLE 4. Traffic Per Cell (Erlangs)

**PPS™-1800 Low-Tier PCS Demonstration Equipment Description**

An operational full-duplex 1.8 GHz PCS prototype system has been built based on the Bellcore FA-NWT-001013, "Generic Framework Criteria for Universal Digital Personal Communications Systems," Issue 2, December 1990. Features and capabilities of this equipment include:

- Full duplex operation
- 75 RF channel tuning range
- Two-branch antenna selection diversity (PORTABLE)
- Two-branch post-detection selection diversity (PORT)
- Design of subscriber unit suitable for field testing as a portable (carry-phone size) with self-contained battery
- Conventional cellular telephone handset provides keypad, display, microphone and speaker to transportable
- Analog and/or digital interfaces from port to wireline network
- 32 kbps speech (optional 32 kbps random data for spectral occupancy tests)
- Signaling protocols to permit portable-originated or portable-terminated calls through the PSTN

A hardware block diagram for the prototype PPS™-1800 Low-Tier Personal Communication System portable subscriber unit is shown in Figure 1. Field programmable gate arrays (FPGA) have been used to implement the modulator and demodulator modules; this provided flexibility for experimentation with these designs yet, at the same time, facilitated the design of a truly portable unit. A Motorola MC68HC11F1 microprocessor controls the system timing and implements the OSI layer 3 functions required for call processing.

The block diagram of the companion prototype port is depicted in Figure 2. In addition to the prototype equipment described in this section, a second generation PPS™-1800 Low-Tier Personal Communication System port has been designed and constructed; this design includes two RF channels in a single port package and provisions for the port to monitor its own transmit frequency band to support the autonomous frequency allocation procedure. In addition a digital network interface has been included in this design. Several of these units are being deployed for demonstrations and for extensive technical field trials.

FPGA implementation of the modem functions is also used in the port; a Motorola MC68332 microprocessor controls the system timing and implements the OSI layer 3 functions. Because these ports were developed as stand-alone demonstration and experimental units, a considerable portion of the per-time slot processing functions are included in the design. In a commercial system, a TDMA port does not process each individual user's timeslot; in effect, it is a 500 kbps radio modem. The per user processing takes place back at the central office or in a radio port control unit that would serve many ports and be housed in a central environmentally controlled location. This is a distinct advantage of TDMA over other multiple access techniques that require per-user processing at the remote port location.

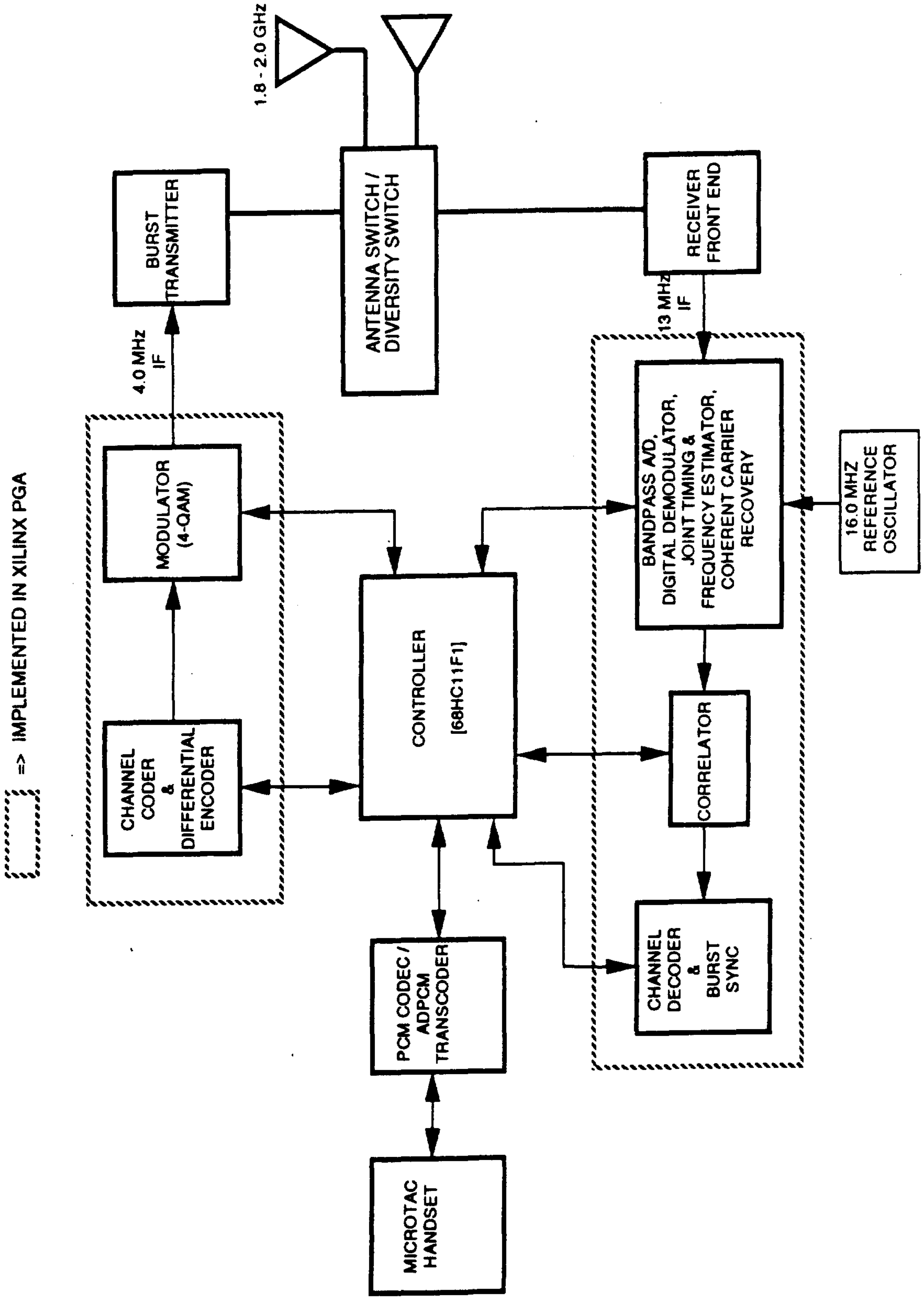


Figure 1. Portable Block Diagram

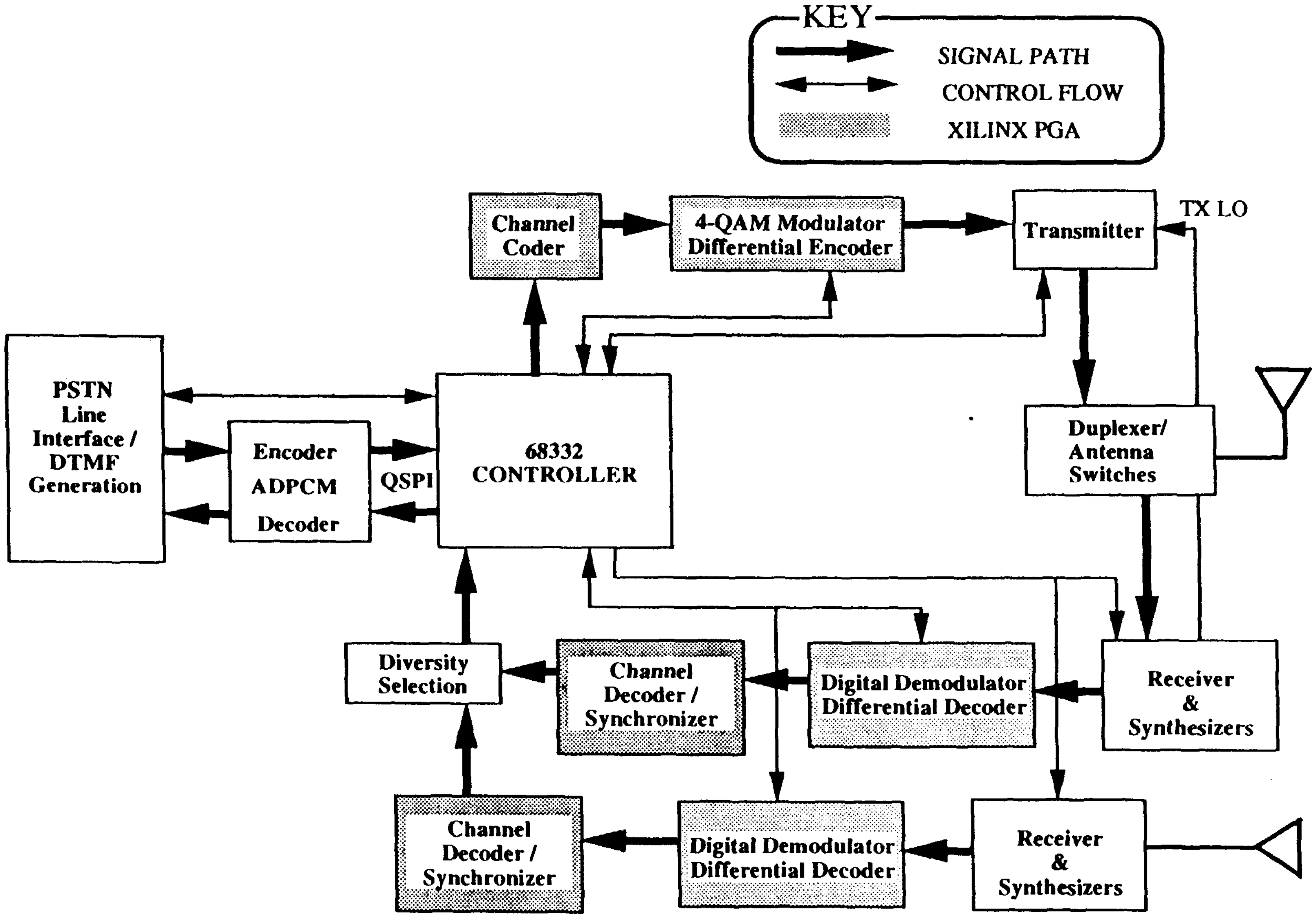


Figure 2. Port Block Diagram